INFO-0091

ACRP Advisory Committee on Radiological Protection

CCRP Comité consultatif de la radioprotection

ACRP-2

RISKS OF LOW-LET RADIATION AS GIVEN IN BEIR-III AND PREVIOUS REPORTS

by the

Advisory Committee on Radiological Protection

A report to the
Atomic Energy Control Board
Ottawa, Canada

July 1982

An Advisory Committee of the Atomic Energy Control Board of Canada — Secretariat: Ottawa, Canada K1P 5S9

Comité consultatif de la Commission de contrôle de l'énergie atomique du Canada — Secrétariat: Ottawa, Canada K1P 5S9

ACRP-2 - RISKS OF LOW-LET RADIATION AS GIVEN IN BEIR-III AND PREVIOUS REPORTS

A report by the Advisory Committee on Radiological Protection to the Atomic Energy Control Board.

ABSTRACT

This report presents the conclusions of a review of the report "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation", BEIR-III, published by the U.S. National Academy of Sciences in 1980 and other related reports.

The committee concludes that, in as far as the estimates of risk from low-LET radiation are concerned, the BEIR-III report does not provide any new data that might suggest that the present dose limits promulgated by the AECB should be changed.

RÉSUMÉ

Le présent rapport donne les conclusions d'une étude du rapport "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation", BEIR-III, publié par le U.S. National Academy of Sciences, en 1980, et d'autres rapports connexes.

Le Comité a conclu que le rapport BEIR-III ne présente aucune nouvelle donnée en matière d'évaluation du risque dû aux rayonnements à faible transfert d'énergie linéique (TEL) qui indiquerait un besoin de changer les limites de dose promulguées par la Commission de contrôle de l'énergie atomique.

NOTA: Cette publication est aussi disponible en français.

The following report was prepared by the Standing Subcommittee on Risk Estimates (SCRE) of the Advisory Committee on Radiological Protection (ACRP) and endorsed by the ACRP at its May 1982 meeting.

The members of the Subcommittee on Risk Estimates at the time of preparation of this report were:

Dr. J. Muller, Chairman
Dr. T.W. Anderson
Dr. G.W. Gibbs
Dr. D.K. Myers
Dr. H.B. Newcombe

Dr. V. Elaguppillai, Secretary

RISKS OF LOW-LET RADIATION AS GIVEN IN BEIR III AND PREVIOUS REPORTS

The Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR) of the U.S. National Academy of Sciences in its report, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation", 1980, (BEIR-III) considered various theoretical models by which the health risks of low levels of ionizing radiation can be estimated by extrapolation from known effects of high radiation doses. Cancer risks are given thus as the values considered to be most probable by the majority of the BEIR committee together with upper and lower limits for estimates of risk. The most probable values for risk of cancer induced by low doses if low-LET or sparsely-ionizing radiations (beta-, gamma- and X-radiation) at dose rates of 5 rad per year or less were estimated by a linear-quadratic dose-response model in BEIR-III; at low dose rates, the quadratic portion of this model disappears to leave only the simpler linear dose-response relationship.

The most probable cancer risks for low-LET radiation at low dose rate as given in BEIR III do not differ greatly from the values suggested by previous committees. The same conclusion applies to risks of genetic defects induced by low-LET radiations. Summary tables from an AECL report are given in Appendix A. In as far as recommendations for dose limits are based on these estimated health effects, the BEIR III report does not provide any good reason to alter presently-used dose limits for low-LET radiations.

It should be noted that:

(i) The above conclusions are not necessarily valid for high-LET radiations (e.g., neutrons, alpha-particles); a separate document on health effects of high-LET radiation is in preparation.

(ii) The 1980 report on Mammography by the U.S. National Council on Radiation Protection and Measurements (NCRP-66) suggests a risk of radiation-induced breast cancer in females greater than that suggested by the International Commission on Radiological Protection in 1977 (ICRP Publication 26); if the assumptions of this NCRP report were correct, the total risk of fatal breast cancer in a mixed population of males and females would be closer to $0.3 - 0.6 \times 10^{-4}$ per rad than to the value of 0.25×10^{-4} per rad suggested by ICRP in 1977 and would thus raise the total risk of fatal cancers in the general population by a small fraction from 1.25×10^{-4} (ICRP 1977) to $1.3 - 1.6 \times 10^{-4}$ per rad. However, the breast cancer risk considered most probable by the majority of the BEIR III committee is equal to or smaller than that suggested by ICRP in 1977.

(iii) A Working Draft of August 11, 1980 on Federal Radiation Protection Guidance for Occupational Exposure which has been circulated by the U.S. Environmental Protection Agency attaches considerably greater importance to the risk due to in utero exposure than might be derived from a reading of the BEIR III report. This particular topic may require further separate consideration at some future date, even though the BEIR III report itself does not suggest a major hazard to fetal development with low-LET radiation at doses below 5 rad per year.

The risk factors for cancers and genetic effects induced by low-LET radiation that are given by ICRP and used by regulatory agencies for setting of dose limits are within the range of values proposed by BEIR III.

In conclusion, therefore, in as far as the estimates of risk from low-LET radiation are concerned, the BEIR III report does not provide any new data that might suggest that the present dose limits proposed by ICRP and promulgated by the Atomic Energy Control Board should be changed.

APPENDIX A

Tables excerpted from report AECL-5715 (Rev. 1)
"Low Level Radiation: A Review of Current Estimates
of Hazards to Human Populations"
by D.K. Myers

TABLE 1

ESTIMATES OF TOTAL LIFETIME RISK OF LEUKEMIAS AFTER EXPOSURE TO SPARSELY-IONIZING RADIATIONS

Source	Leukemias/10^6 persons.rad
ICRP, 1966 (5)	20
UNSCEAR, 1971 (3)	14-40
BEIR, 1972 (1)	26-37
UNSCEAR, 1977 (4)	15-25
ICRP, 1977 (6)	20
BEIR, 1980 (2)	23 (range <0.3 to 48)

TABLE 2

ESTIMATES OF TOTAL LIFETIME RISK OF RADIATION-INDUCED CANCER FOR BETA-, GAMMA- OR X-RADIATION

Source of Data	Fatal cancers /10^6 persons.rad	Curable cancers* /10^6 persons.rad	Total
UNSCEAR, 1977 (4)	100 (range 75-175)	∿100	∿200
ICRP, 1977 (6)	∿125 (100 for males, 150 for females)	∿125	∿250
BEIR, 1980 (2)**	67-226 (range <10-500)	30-45 (range <4-770)	110-270 (range <14-1270)

* Curable cancers are primarily skin cancers, thyroid cancers and about half of the total breast cancers. A small fraction of skin cancers and thyroid cancers are included in the category of fatal cancers.

** The range of values given in the first row represents those numbers calculated by absolute risk and relative risk models, respectively, and agreed upon by the majority of the scientists on the BEIR III committee as the most probable risk estimates (2). The numbers calculated by these two models become very similar and approach the lower limit of the range in the first row for persons age 35 and over at the time of exposure (see Table 5). The second and wider range of values given in brackets in the above table includes the lower and upper range of the risk estimates suggeted by the BEIR III report (2). The risks of densely ionizing radiations such as fast neutrons or alpha particles are suggested in BEIR III to be twice as high per rem as those given in the first row (2).

TABLE 3

1977 ICRP (6) AND 1980 BEIR (2) ESTIMATES OF LIFETIME RISK OF DIFFERENT TYPES OF FATAL CANCERS AFTER EXPSOURE TO SPARSELY IONIZING RADIATIONS

Type of Cancer	Fatal cancers/10^6 persons.rad	
	ICRP (6)	BEIR (2)*
Leukemia	20	20-23
Bone	5	0.5
Lung	20	17-67
Thyroid	5	4-17
Breast	25 (average of 0 for males and of 50 for females)	6-25 (average of 0 for males and of 13-51 for females)
All other tissues	50	20-93
Total	125	67-226

* These values are derived from the most probable total risk estimates as indicated in the bottom row of Table 2, with further apportionment for various tissues as suggested by Tables V-15 and V-16 of the 1980 BEIR report (2). The range of risk estimates represents values calculated by the absolute and relative risk models (2); as noted in Table 5, only the lower of this range of risk estimates is applicable to workers or other persons over age 35 at the time of exposure. Both higher and lower values can be derived from other tables in this report (2) but these other values were considered to be less probable by the majority of the BEIR committee members.

TABLE 4

AUTHOR'S CALCULATION OF THE RISK OF RADIATION-INDUCED BREAST CANCER IN NORTH AMERICAN FEMALES, BASED ON A LINEAR DOSE-RESPONSE MODEL*

Age in years at time of exposure to radiation	Average life expectancy in years after age at exposure	Years of life at risk	Total risk per 10^6 females per year per rad	Lifetime risk of radiation-induced breast cancer per 10^6 females per rad	
				Curable	Fatal
5 (0-9)	73	-	0	0	0
15 (10-19)	63	46	10.4 - 22.4	290-630	190-400
25 (20-29)	53	43	6.6 - 8.7	170-230	110-150
35 (30-39)	44	34	6.6 - 8.7	140-180	90-120
45 (40-49)	34	24	6.6 - 8.7	100-130	60-80
55 (50-59)	25.5	15.5	6.6 - 8.7	60-80	40-50
65 (60-69)	17.5	7.5	6.6 - 8.7	30-40	20-30
Average for females with a life expectancy of 76 years**				90-150	60-100

* The calculations in this table are essentially similar to those carried out by Boice *et al.* (8) but are extrapolated over a more complete range of ages at time of exposure. Data on average life expectancy are taken from Canadian life tables for 1971. Years at risk equals years of life expectancy minus a 10 year latency period, with minor revisions for the age 10-19 group as suggested in various rports (2,7,8). Total risk estimates are taken from Boice *et al.* (8, see also 2,7,) and divided into curable or fatal cancers on the assumption that 39% of all induced breast cancers are currently fatal (2). All lifetime risk estimates were rounded to the nearest 10 for simplicity.

** The lifetime risks for various age groups as given in the upper portion of this table are the more appropriate values for consideration when dealing with the practical medical problem of mammography of a female of known age. The average for females with a life expectancy of 76 years is the more appropriate value for consideration when dealing with a whole population in which the females are assumed to be exposed continuously to radiation from environmental sources from birth to death. Consideration of relative risk models as well as absolute risk models (8) would provide a total range of about 60-120 fatal breast cancers per 10^6 females per rad, slightly greater than the range of 60-100 indicated above.

TABLE 5

1980 BEIR (2) ESTIMATES OF PROBABLE LIFETIME RISK OF FATAL CANCERS INDUCED BY EXPOSURE AT DIFFERENT AGES TO LOW LEVELS OF BETA-, GAMMA-, AND X-RADIATIONS*

Ages during which persons are exposed to 0.01 Sv (1 rem) each year	Fatal cancers/10^6 persons.rad			
	Absolute Risk Model		Relative Risk Model**	
	Male	Female	Male	Female
Lifetime (0-71)	57	77	167	198
20-65	61	86	109	144
35-65	54	79	53	81
50-65	54	78	58	89
0-20	∿65	∿ 80	∿350	∿380
20-35	75	100	222	270
35-50	54	79	49	73

* All values in this table were calculated from Table V-16 and V-19 of the 1980 BEIR report (2) and represent estimates of numbers of fatal cancers expected to result from continuous exposure of the population to 1 rad (10 mGy) of sparsely-ionizing radiation per year during the years indicated in the table. The BEIR III values in Table 2 above were taken directly from Table V-4 of the 1980 BEIR report (2), which provides a 23% larger value for the relative risk data after a single exposure of the whole population to 10 rads. The risks for densely-ionizing radiations such as fast neutrons or alpha particles are thought to be twice as high per rem as those given in this table (2).

** The values given are the sum of the absolute risk estimates for leukemias and bone cancers plus the relative risk estimates for all other fatal cancers; no relative risk estimates were given for leukemias and bone cancers (2).

TABLE 6

ESTIMATES OF NUMBERS OF GENETIC DEFECTS INDUCED BY EXPOSURE TO HUMANS TO RADIATION PRIOR TO PARENTHOOD

Source of data	Genetic diseases/10^6 persons.rad	
	Apparent in first generation	Total number at equilibrium
ICRP, 1966 (5)	20	8,500
UNSCEAR, 1972 (3)	6-15	300
BEIR, 1972 (1)	12-200	60-1500
UNSCEAR, 1977 (4)	20-63	185
ICRP, 1977 (6)	-*	~ 200
BEIR, 1980 (2)	5-75	60-1100

* No value is given for the first generation but the sum of the values for the first and second generation is given as about 100 per 10^6 persons.rad.

TABLE 7

SUMMARY OF RISK ESTIMATES FOR A GENERAL POPULATION EXPOSED TO LOW-LEVEL IRRADIATION OF THE WHOLE BODY

Biological effect	ICRP value (6) for risk estimates (per rad per 10^6 persons exposed)	Range of BEIR III values (2) for risk estimates (per rad per 10^6 persons exposed)
Fatal cancers induced in the irradiated population	125	~10 to 500
Curable cancers induced in the irradiated population	125	~ 4 to 770
Total genetic diseases in all subsequent descendants of the irradiated population	80	24 to 440

REFERENCES

(1) BEIR report. The effects on populations of exposure to low levels of ionizing radiation. Advisory Committee on the Biological Effects of Ionizing Radiations, U.S. National Academy of Sciences, Washington, DC (1972).

(2) BEIR III report. The effects on populations of exposure to low levels of ionizing radiation. Advisory Committee on the Biological Effects of Ionizing Radiations, U.S. National Academy of Sciences, Washington, DC (1980).

(3) UNSCEAR 1972 report. Ionizing radiation: levels and effects. United Nations Scientific Committee on the Effects of Atomic Radiation, United Nations, New York (1972).

(4) UNSCEAR 1977 report. Sources and effects of ionizing radiation. United Nations Scientific Committee on the Effects of Atomic Radiation, United Nations, New York (1977).

(5) ICRP Publication 8. The evaluation of risks from radiation. Pergamon Press, New York (1966).

(6) ICRP Publication 26. Recommendations of the International Commission on Radiological Protection. Annals of the ICRP, Vol. 1, No 3 (1977).

(7) NCRP Report No. 66. Mammography. National Council on Radiation Protection and Measurements, Washington, DC (1980).

(8) J.D. Boice, C.E. Land, R.E. Shore, J.E. Norman and M. Tokunaga: Risk of breast cancer following low-dose radiation exposure. Radiology, Vol. 131, p.589-597 (1979).